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Preoperative ultrasonographic subcutaneous tissue thickness as a predictor of surgical site infection following open appendectomy for acute appendicitis: A prospective observational study

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Abstract

Background: Surgical site infection (SSI) remains one of the most common postoperative complications following appendectomy. Body mass index (BMI) has traditionally been used to estimate surgical risk; however, it does not reflect local adiposity at the incision site. Subcutaneous tissue thickness (SCT), measured preoperatively by ultrasonography, may represent a more accurate predictor of SSI.

Methods: This prospective observational study included 192 patients aged 12 years and above undergoing emergency open appendectomy for uncomplicated acute appendicitis at a tertiary care centre. Preoperative ultrasonographic measurement of SCT was performed at the point of maximal tenderness. Patients were followed on postoperative days 1, 3, 7, and 30. SSI was assessed using the Southampton Wound Assessment Scale. Receiver operating characteristic (ROC) curve analysis was used to determine the predictive value of SCT for SSI.

Results: The mean SCT was 14.68 ± 5.89 mm. SSI occurred in 113 patients (58.9%, Southampton Grade 1 – 4). Patients who developed SSI had significantly greater SCT than those without SSI (17.22 ± 6.12 mm vs. 11.05 ± 2.92 mm, $p<0.001$). ROC analysis demonstrated good discriminatory ability (AUC=0.833, 95% CI 0.775–0.890, $p<0.001$). An SCT cutoff value greater than 15 mm yielded a sensitivity of 62.8%, specificity of 93.7%, positive predictive value of 93.4%, and diagnostic accuracy of 75.5%.

Conclusions: Preoperative ultrasonographic SCT measurement is a significant predictor of postoperative SSI following open appendectomy. Routine assessment of SCT may facilitate risk stratification and implementation of targeted preventive strategies.

Keywords: Acute appendicitis, Surgical site infection, Subcutaneous tissue thickness, Ultrasonography, Open appendectomy, Risk prediction

Introduction

Acute appendicitis remains one of the most common surgical emergencies worldwide and continues to be a leading cause of acute abdominal pain requiring urgent operative intervention. The lifetime risk is approximately 7–8%, with peak incidence during the second and third decades of life. Despite improvements in diagnostic imaging, perioperative care, antimicrobial therapy, and minimally invasive techniques, appendectomy remains the standard treatment for most patients. Although generally regarded as safe, appendectomy is associated with complications; among these, surgical site infection (SSI) is one of the most frequent and clinically significant adverse outcomes.

Surgical site infections, defined as infections at or near the operative incision within 30 days of surgery. SSIs increase postoperative morbidity through delayed wound healing, greater pain, prolonged hospitalization, additional antibiotic use, more outpatient visits, and, in severe instances, reoperation or readmission. They also impose a considerable economic burden on health systems, especially in resource-limited settings where infection surveillance and control programs may be suboptimal. Reported SSI incidence after appendectomy varies widely and depends on patient factors, disease severity, and surgical approach, ranging from less then 5% in uncomplicated cases to over 20% in complicated appendicitis. Risk factors include advanced age, diabetes mellitus, smoking, malnutrition, obesity, prolonged operative time, perforated appendix, and inadequate perioperative antibiotic prophylaxis. Early identification of high-risk patients is essential to guide targeted preventive measures and improve outcomes.

Obesity is a recognized risk factor for postoperative wound complications. Excess subcutaneous adipose tissue interferes with wound healing via impaired perfusion, reduced tissue oxygenation, attenuated local immune

responses, increased wound tension, and larger dead space. Body mass index (BMI) is the conventional clinical measure of obesity, it has significant limitations as it measures overall mass relative to height but cannot distinguish adiposity from lean body mass and fails to assess regional fat distribution, which may be more relevant to local wound-healing conditions.

Subcutaneous tissue thickness (SCT) has emerged as a potentially better, site-specific predictor of wound complications. SCT directly measures adipose tissue at the surgical site and may better reflect local factors that predispose to infection, including decreased vascularity, tissue hypoxia, reduced antibiotic penetration, and higher bacterial colonization. Studies across surgical specialties—colorectal, gynecological, spinal, and general surgery—have demonstrated that local SCT correlates more strongly with wound complications than BMI. Preliminary investigations in appendectomy patients similarly indicate that increased SCT associates with higher postoperative wound infection rates, suggesting SCT might function as an independent risk factor for SSI.

Ultrasonography provides a practical method to measure SCT preoperatively. It is noninvasive, inexpensive, widely available, rapid, and free of ionizing radiation—features that make it suitable for emergency surgical settings. Bedside ultrasonographic assessment of SCT could enable risk stratification and inform tailored preventive strategies, such as optimized antibiotic prophylaxis, modified wound closure techniques, and increased postoperative surveillance.

Despite growing evidence, data from the Indian population are limited, and heterogeneity in measurement methods and cutoff values has produced inconsistent results internationally. This prospective observational study therefore evaluates the association between preoperative ultrasonographically measured SCT and development of SSI in patients undergoing open appendectomy for acute appendicitis.

Materials and methods

Study Design and Setting

This prospective observational cohort study was conducted in the Department of General Surgery in collaboration with the Department of Radiodiagnosis at Vardhman Mahavir Medical College (VMMC) and Safdarjung Hospital, New Delhi, India, over a period of 18 months. The study aimed to evaluate the association between preoperative ultrasonographically measured subcutaneous tissue thickness (SCT) and the development of postoperative surgical site infection (SSI) in patients undergoing emergency open appendectomy for acute appendicitis.

The study protocol was approved by the Institutional Ethics Committee of VMMC and Safdarjung Hospital before commencement. Written informed consent was obtained from all participants or their legal guardians prior to enrollment.

Study Population

Patients presenting to the emergency department with a clinical diagnosis of acute appendicitis and planned for emergency open appendectomy were screened for eligibility.

Inclusion Criteria

Patients fulfilling all the following criteria were included:

1. Age greater than 12 years.
2. Clinical features suggestive of acute appendicitis.
3. Ultrasonographic confirmation of acute appendicitis.
4. Undergoing emergency open appendectomy.

Exclusion Criteria

1. Immunocompromised patients, including those with diabetes mellitus, HIV infection, receiving immunosuppressive therapy, or chronic steroid treatment.
2. History of previous abdominal surgery.
3. Complicated appendicitis with generalized peritonitis requiring midline laparotomy.

Sample Size

The sample size was estimated using previously published studies evaluating SCT as a predictor of SSI following appendectomy. Assuming an anticipated sensitivity of approximately 80%, a confidence level of 95%, and an acceptable margin of error of 5%, the required sample size was calculated. A total of 192 consecutive eligible patients were enrolled and included in the final analysis.

Clinical Evaluation

At admission, all patients underwent detailed history taking, physical examination, and routine laboratory investigations. The Alvarado score was calculated for each patient based on clinical symptoms, physical findings, and laboratory parameters. Patients with higher scores suggestive of acute appendicitis underwent ultrasonographic evaluation for confirmation of diagnosis.

Table 1: Alvarado Scoring System

Alvarado score	
Symptoms	
Abdominal pain that migrates to the right iliac fossa	1
Anorexia (loss of appetite)	1
Nausea or vomiting	1
Tenderness in the right iliac fossa	2
Signs	
Rebound tenderness	1
Fever of 37.3°C or more	1
Laboratory Parameters	
Leukocytosis >10,000	2
Neutrophilia >70%	1
Total	10

Ultrasonographic Assessment

Preoperative ultrasonography was performed by an experienced radiologist using a GE LOGIQ E8 ultrasound machine equipped with a 7.5-MHz high-frequency linear transducer. Patients were examined in the supine position. Ultrasonographic findings including appendiceal diameter, wall thickness, periappendiceal fluid collection, and surrounding inflammatory changes were documented.

Measurement of Subcutaneous Tissue Thickness

Subcutaneous tissue thickness was defined as the perpendicular distance between the skin surface and the external oblique muscle aponeurosis at the point of maximal tenderness in the right iliac fossa. To ensure measurement accuracy, excessive probe pressure was avoided, measurements were obtained during quiet respiration, and three separate readings were recorded for each patient. The mean value was used for final analysis and expressed in millimeters (mm).

Surgical Procedure

Following confirmation of diagnosis, all patients underwent emergency open appendectomy under standard anesthesia protocols. A standardized operative technique was followed using either a Lanz incision or a Grid-Iron (McBurney's) incision depending on surgeon preference and operative findings. Intraoperative observations including presence of fecolith, gangrene, localized perforation, periappendiceal contamination, and operative complications were recorded. All wounds were irrigated with normal saline prior to layered closure of wound.

Postoperative Follow-up and Outcome Assessment

Patients were followed postoperatively on days 1, 3, 7, and 30. Wound healing was assessed using the Southampton Wound Assessment Scale. Surgical site infection was defined as any wound demonstrating signs of infection according to Southampton criteria. The primary outcome was development of postoperative SSI. Secondary outcomes included length of hospital stay, timing of SSI occurrence, wound grade, need for additional wound care, and readmission due to wound-related complications.

Table 2: Southampton Wound Assessment Scale

0	Normal Healing
1	Erythema with signs of inflammation at local site
2	Clear or hemoserous discharge
3	Purulent discharge
4	Deep or severe wound infection with or without tissue breakdown

Data Collection and Statistical Analysis

Clinical, radiological, operative, and postoperative data were prospectively recorded using standardized data collection forms. Data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 21.0.

Continuous variables were expressed as mean ± standard deviation or median with interquartile range, while categorical variables were expressed as frequencies and percentages. Comparisons between groups were performed using Student's t-test, Mann–Whitney U test, Chi-square test, or Fisher's exact test as appropriate. Receiver operating characteristic (ROC) curve analysis was performed to evaluate the predictive performance of SCT and determine the optimal cutoff value for predicting SSI. Sensitivity, specificity, positive predictive value, negative predictive value, diagnostic accuracy, and area under the curve (AUC) were calculated. A p-value <0.05 was considered statistically significant.

Results

Patient Characteristics

A total of 192 patients with acute appendicitis who underwent emergency open appendectomy were included in the study. The mean age of the study population was 30.56 ± 14.10 years (range: 13–78 years). The majority of patients belonged to the 21–30-year age group (34.4%), followed by the 13–20-year age group (27.1%). There was a marked male predominance, with 157 (81.8%) males and 35 (18.2%) females.

The mean Alvarado score was 7.76 ± 1.04, while the mean appendiceal diameter measured on ultrasonography was 9.33 ± 2.09 mm. The mean preoperative subcutaneous tissue thickness (SCT) was 14.68 ± 5.89 mm.

Table 3: Baseline Demographic and Clinical Characteristics of the Study Population (n = 192)

Variables	Values
Age (years), mean ± SD	30.56 ±14.10
Male sex, n (%)	157 (81.8)
Female sex, n (%)	35(18.2)
Alverado score, mean ±SD	7.76 ±1.04
Appendix diameter (mm), mean ± SD	9.33 ± 2.09
SCT (MM), mean ± SD	14.68 ±5.89
Hospital stay (days), mean ±SD	3.04±1.55

Clinical Presentation

Abdominal pain was present in all patients (100%). Nausea and vomiting were observed in 150 patients (78.1%), anorexia in 126 patients (65.6%), and fever in 119 patients (62.0%). Right iliac fossa tenderness was present in all patients.

Table 4: Clinical Characteristics of Patients

Clinical presentation	Frequency	Percentage
Migratory pain	115	59.90%
Anorexia	126	65.63%
Nausea	150	78.13%
Tenderness	192	100.00%
Rebound tenderness	116	60.42%
Fever >99.1 ºF	119	61.98%
Leukocytosis >10K	160	83.33%
Neutrophilia	160	83.33%

Incidence of Surgical Site Infection

Of the 192 patients studied, 113 (58.9%) developed surgical site infection (Southampton Grade 1 – 4) during follow-up. The remaining 79 patients (41.1%) had uncomplicated wound healing. The majority of infections became apparent during the first postoperative week.

Table 5: Southampton wound assessment during follow-up

Southampton Grade	POD 1	POD 3	POD 7	POD 30
Normal healing	42.2%	59.4%	88.0%	100%
Grade 1	34.9%	9.9%	11.5%	0%
Grade 2	22.4%	13.5%	0.5%	0%
Grade 3	0.5%	14.6%	0%	0%
Grade 3	0%	2.6%	0%	0%

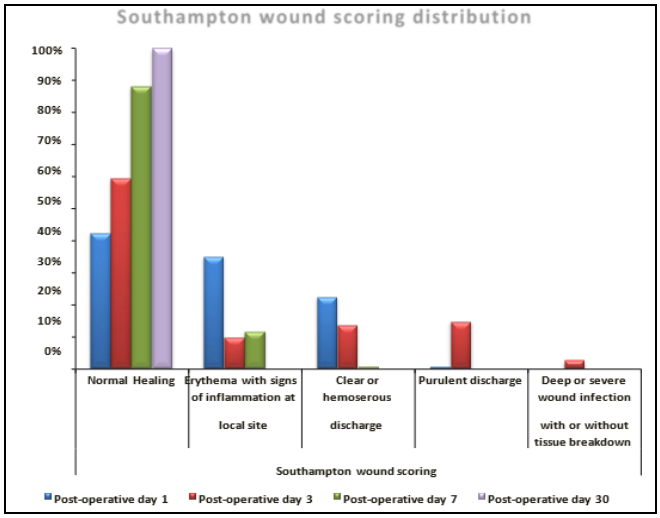

Fig 1: Showing Southampton wound scoring distribution.

Comparison Between Patients With and Without Surgical Site Infection: Patients who developed SSI had significantly greater subcutaneous tissue thickness than those who did not develop SSI. The mean SCT in the SSI group was 17.22 ± 6.12 mm compared with 11.05 ± 2.92 mm in the non-SSI group ($p < 0.001$).

Table 6: Comparison Between SSI and Non-SSI Groups

Variable	SSI (n= 113)	No SSI (n=79)	P value
Age (years)	31.12 +- 13.89	29.76 +- 14.42	0.45
Male sex (%)	82.3	81.0	0.82
Alvarado score	7.88 +- 1.02	7.59 +- 1.05	0.06
Appendix diameter (mm)	9.76 +_ 2.22	8.72 +_ 1.81	0.01
SCT (mm)	17.22 +- 6.12	11.05 +_ 2.92	<0.001
Hospital stay (days)	3.91 +- 1.41	1.81 +_ 0.64	<0.001

Diagnostic Performance of Subcutaneous Tissue Thickness: Receiver Operating Characteristic (ROC) curve analysis demonstrated excellent discriminatory ability of SCT for predicting postoperative SSI. The area under the ROC curve (AUC) was 0.833 (95% CI: 0.775–0.890; $p < 0.001$), indicating good predictive performance. The optimal SCT cutoff value identified was >15 mm.

Table 7: Diagnostic Performance of SCT in Predicting SSI

Parameters	Value
Optimal cutoff	>15 mm
Sensitivity	62.83 %
Specificity	93.67%
Positive predictive value	93.40%
Negative predictive value	63.80%
Diagnostic Accuracy	75.52%
AUC	0.833
95% CI	0.775 – 0.890
P value	<0.001

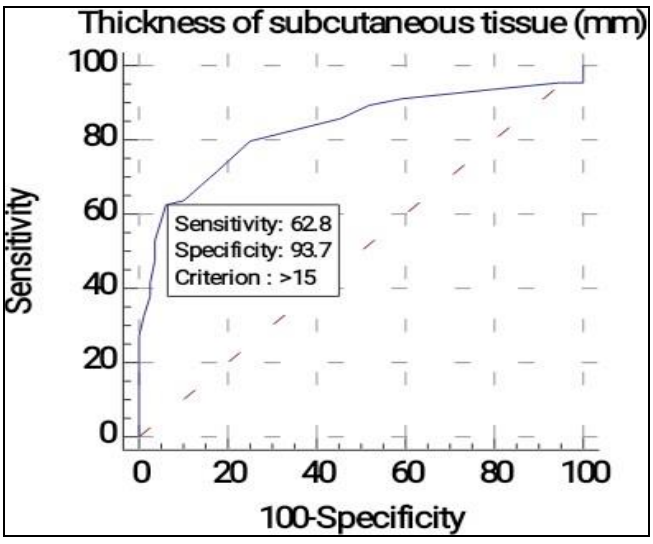

Fig 2: Receiver Operating Characteristic (ROC) Curve for SCT.

Relationship Between SCT and SSI: Patients with SCT >15 mm demonstrated a substantially higher risk of postoperative SSI compared with patients having SCT ≤15 mm. This threshold showed excellent specificity for identifying patients at high risk for wound infection following appendectomy.

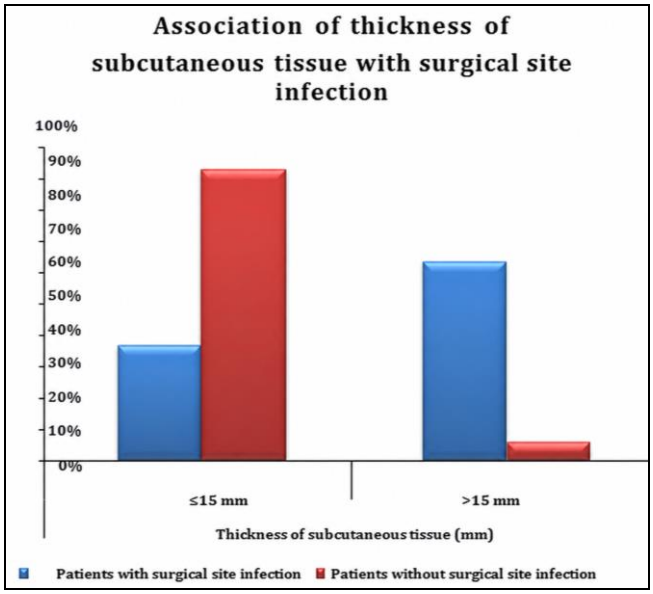

Fig 3: Mean SCT in Patients with and Without SSI.

Length of Hospital Stay: Development of SSI significantly increased postoperative hospital stay. Patients with SSI had a mean hospitalization of 3.91 ± 1.41 days compared with 1.81 ± 0.64 days in patients without SSI ($p < 0.001$), representing more than a twofold increase in length of stay.

Discussion

Surgical site infection (SSI) remains one of the most frequent postoperative complications following appendectomy and continues to contribute significantly to patient morbidity, prolonged hospitalization, increased healthcare expenditure, and delayed recovery. Identification of reliable preoperative predictors of SSI is therefore essential to facilitate risk stratification and implementation of targeted preventive measures. The present prospective observational study evaluated the role of preoperative ultrasonographically measured subcutaneous tissue thickness (SCT) in predicting SSI among patients undergoing emergency open appendectomy for acute appendicitis.

The principal finding of this study was the significant association between increased SCT and the development of postoperative wound infection. Patients who developed SSI had significantly greater SCT values than those who remained infection-free (17.22 ± 6.12 mm vs. 11.05 ± 2.92 mm, $p < 0.001$). Furthermore, ROC curve analysis demonstrated good discriminatory performance, with an area under the curve (AUC) of 0.833. An SCT threshold of >15 mm provided high specificity (93.7%) and acceptable sensitivity (62.8%) for predicting SSI, suggesting that SCT may serve as a clinically useful marker for identifying patients at increased risk of postoperative wound complications.

The relationship between increased SCT and SSI is biologically plausible. Adipose tissue is relatively poorly vascularized compared with muscle and connective tissue, resulting in reduced tissue perfusion and oxygen delivery. Adequate tissue oxygenation is critical for collagen synthesis, angiogenesis, and neutrophil-mediated bacterial killing during wound healing. Increased subcutaneous fat may therefore create a relatively hypoxic environment that predisposes to infection. In addition, thick adipose tissue

may impair antibiotic penetration, increase wound tension, and promote dead-space formation, seroma accumulation, and hematoma development, all of which provide favorable conditions for bacterial proliferation and delayed wound healing.

Our findings are consistent with previously published literature. Thapa *et al*. reported that increased ultrasonographically measured SCT was associated with a significantly higher incidence of SSI following appendectomy. Similarly, Karthick and Arsath demonstrated a strong relationship between right iliac fossa SCT and postoperative wound infection in patients undergoing open appendectomy. A recent meta-analysis by Bahardoust *et al*. further confirmed that increasing SCT substantially elevates the risk of SSI across a variety of surgical procedures. Comparable observations have also been reported in colorectal surgery, cesarean section, spinal surgery, and gynecological procedures, highlighting the importance of local adiposity as a determinant of wound-related outcomes.

Additional, these patients have prolonged hospital stay among patients who developed SSI. Patients with wound infection required more than twice the duration of hospitalization compared with those without infection. Prolonged hospitalization not only increases treatment costs but also exposes patients to additional risks, including nosocomial infections, psychological stress, and delayed return to normal daily activities. Therefore, effective identification of high-risk patients may contribute to both improved patient outcomes and more efficient utilization of healthcare resources.

Conclusion

The findings of the present study suggest that preoperative ultrasonographic assessment of subcutaneous tissue thickness may serve as a simple, inexpensive, non-invasive, and readily available tool for risk stratification in patients undergoing open appendectomy. Identification of high-risk patients before surgery may facilitate implementation of targeted preventive measures including meticulous wound closure, enhanced perioperative wound care, optimization of antibiotic prophylaxis, and closer postoperative surveillance. Such strategies may help to reduce surgical site infections, shorten hospital stay, improve patient outcomes, and decrease healthcare costs.

Strengths of the Study

This prospective study utilized a standardized ultrasonographic protocol for measuring subcutaneous tissue thickness (SCT), ensuring reliable and reproducible assessment. Postoperative wound evaluation was performed using the validated Southampton Wound Assessment Scale. Additionally, the study included a relatively large cohort of patients undergoing open appendectomy, providing real-world evidence regarding the association between SCT and surgical site infection.

Limitations of the Study

This was a single-center study, which may limit the generalizability of the findings. Interobserver variability in ultrasonographic measurements was not formally assessed. Potential confounding factors such as nutritional status, smoking, operative duration, surgeon experience, and antibiotic compliance were not evaluated in detail.

Recommendations

Future multicenter prospective studies involving larger patient populations are required to validate the predictive utility of SCT across different healthcare settings. Comparative studies evaluating SCT against traditional obesity indices such as body mass index may further clarify its relative clinical value.

Conflict of Interests: The authors declare that they have no competing interests.

Authors' Contributions

Conceptualization, study design, data acquisition, statistical analysis, interpretation of results, manuscript preparation, manuscript review, and final approval of the submitted version were performed by the authors. All authors read and approved the final manuscript.

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